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**(54) Vehicle crash predictive and evasive operation system by neural networks**

Steuerungssystem mit neuronalem Netzwerk zum Voraussagen und Vermeiden von  
Zusammenstößen eines Fahrzeuges

Système de commande à réseau neuronal pour prévoir et éviter les collisions pour un véhicule

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**EP 0 582 236 B1**

## Description

### Background of the Invention

The invention relates to an apparatus for predicting and evading potential crash of a vehicle and for predicting real crash of a vehicle and acting correspondingly according to the preamble of claim 1. Furthermore, the invention relates to a method according to the preamble of claim 9.

A driver has an unconscious and immediate sense of various conditions through the objects in view and, as a case may be, he must take an action to evade any possible crash or collision. However, drivers will often be panicked at the emergency of above their sense. Such a panicked driver may sometimes be the last one who can cope with the emergency to ensure the active safety of the vehicle. Besides, the response delay to stimuli in varying degrees is inherent to human beings, so that it is impossible in some cases to evade crash or danger by physical considerations. With this respect, various techniques have been developed to evade collision by means of mounting on a vehicle a system for determining the possibility of crash in a mechanical or electrical manner before it happens. Accidents could be reduced if drivers had an automatic system or the like warning of potential collision situations.

An apparatus comprising a system for predicting and evading crash of a vehicle including image pick-up means, crash predicting means, safety drive ensuring means and a neural network according to the preamble of claim 1 is known from JP-A-4008639 (Abstract).

In WO-A-90/02985 a system for predicting and evading crash of a vehicle comprising a sensor system mounted on the vehicle for observing the surrounding in a running direction is disclosed. A crash predicting system is successively supplied with actual sensor system data for predicting occurrence of crash between the vehicle and potential dangerous objects on the roadway and for producing an operational signal when there is possibility of crash. In response to the operational signal the vehicle is operated to evade the crash.

Another moveable device with supersonic sensors and a neural network to further process the data taken by the supersonic sensor system is disclosed in DE-A-4001493. Furthermore, in this moveable device learning data are used to train the neural network.

In general, neural networks are known from "Parallel distributed Processing", Vol. 1: Foundations, A Bradford Book, The MIT Press, Cambridge, Mass., London, England, by David E. Rumelhart, James L. McClelland and the PDP Research Group.

An automobile collision avoidance radar is typically used as this automatic system. Such an automobile collision avoidance radar is disclosed in, for example, M. Kiyoto and A. Tachibana, Nissan Technical Review: Automobile Collision-Avoidance Radar, Vol. 18, Dec. 1982 that is incorporated by reference herein in its

entirety. The radar disclosed comprises a small radar radiation element and antennas installed at the front end of a vehicle. A transmitter transmits microwaves through the radiation element towards the headway. The microwave backscatter from a leading vehicle or any other objects as echo returns. The echo returns are received by a receiver through the antennas and supplied to a signal processor. The signal processor carries out signal processing operation to calculate a relative velocity and a relative distance between the object and the vehicle. The relative velocity and the relative distance are compared with predetermined values, respectively, to determine if the vehicle is going to collide with the object. The high possibility of collision results in activation of a proper safety system or systems.

However, the above mentioned radar system has a disadvantage of faulty operation or malfunctions, especially when the vehicle implementing this system passes by a sharp curve in a road. The radar essentially detects objects in front of the vehicle on which it is mounted. The system thus tends to incorrectly identify objects alongside the road such as a roadside, guard rails or even an automobile correctly running on the adjacent lane.

An intelligent vehicle has also been proposed that comprises an image processing system for cruise and traction controls. Ever-changing views spreading ahead the vehicle are successively picked up as image patterns. These image patterns are subjected to pattern matching with predetermined reference patterns. The reference patterns are classified into some categories associated with possible driving conditions. For example, three categories are defined for straight running, right turn and left turn. When a matching result indicates the presence of potentially dangerous objects in the picked up image, a steering wheel and a brake system are automatically operated through a particular mechanism to avoid or evade crash to that object.

The image processing system of the type described is useful in normal driving conditions where the pattern matching can be effectively made between the image patterns successively picked up and the reference patterns for safety driving control. However, image patterns representing various conditions on the roadway should be stored previously in the intelligent vehicle as the reference patterns. Vehicle orientation at initiation of crash varies greatly, so that huge numbers of reference patterns are required for the positive operation. This means that only a time-consuming calculation will result in a correct matching of the patterns, which is not suitable for evading an unexpected crash.

It is, of course, possible to increase operational speed of the pattern matching by using a large dedicated image processor. However, such a dedicated processor is generally complex in structure and relatively expensive, so that it is difficult to apply the same as the on-vehicle equipment. In addition, on-vehicle image processors, if achieved, will perform its function

sufficiently only in the limited applications such as a supplemental navigation system during the normal cruising.

### Summary of the Invention

An object of the present invention is to provide a system for predicting and evading crash of a vehicle using neural networks.

Another object of the present invention is to provide a system capable of training neural networks by means of collecting image data representing ever-changing vistas along the travel direction of a vehicle until the vehicle collides with something.

It is yet another object of the present invention to provide a system for predicting crash through matching operation between data obtained on driving a vehicle and data learned by neural networks. It is still another object of the present invention to provide a system for evading crash of a vehicle using neural networks to actuate a vehicle safety system for protecting an occupant.

In order to achieve the above-mentioned objects, an apparatus comprising the features of claim 1 and a method comprising the features of claim 9 are provided.

The neural network comprises at least an input layer and an output layer, and the training data are supplied to the input layer while the output layer is supplied with, as teacher data, flags representing expected and unexpected crash, respectively, of the vehicle. In addition, the neural network may comprise a two-dimensional self-organizing competitive learning layer as an intermediate layer.

Other advantages and features of the present invention will be described in detail in the following preferred embodiments thereof.

### Brief Description of the Drawings

Fig. 1 is a block diagram of a conventional system for predicting and evading crash of a vehicle;

Fig. 2 is a schematic view showing a processing element in a typical neural network;

Fig. 3 is a graphical representation of a sigmoid function used as a transfer function for training neural networks;

Fig. 4 is a block diagram of a system for predicting and evading crash of a vehicle using neural networks according to the first embodiment of the present invention;

Fig. 5(a) is a schematic structural diagram of a crash predicting circuit in Fig. 4 realized by a neural network of three layers;

Fig. 5(b) shows an example of an input layer consisting of a two-dimensional array of processing elements of the neural network shown in Fig. 5(a);

Figs. 6(a) and 6(b) are exemplified views picked up, as the training image data supplied to the neural

network, at different time instances during driving an experimental vehicle;

Fig. 7 is a view showing an example of an image data obtained during driving a utility vehicle;

Fig. 8 is a view showing another example of an image data obtained during driving a utility vehicle; and

Fig. 9 is a block diagram of a system for predicting and evading crash using neural networks according to the second embodiment of the present invention.

### Detailed Description of the Preferred Embodiments

A conventional system for predicting and evading crash of a vehicle is described first to facilitate an understanding of the present invention. Throughout the following detailed description, similar reference numerals refer to similar elements in all figures of the drawing.

In the following description, the term "crash" is used in a wider sense that relates to all unexpected traffic accidents. Accidents other than crash include a turnover or fall of a vehicle, with which the phenomenon of "crash" is associated in some degrees therefore the use of term crash as a cause of traffic accidents.

As shown in Fig. 1, an image pick-up device 21 is mounted at a front portion of an automobile 10 to pick up ever-changing images as analog image data. This image pick-up device 21 is any one of suitable devices such as a charge-coupled-device (CCD) camera. The image data are subject to sampling for a sampling range  $\Delta T$  during a predetermined sampling period  $\Delta t$ . The image data are collected up to crash. In this event, the image pick-up range of the image pick-up device 21 corresponds to a field of view observed through naked eyes.

The image pick-up device 21 is connected to an input interface 22. The analog image data obtained by the image pick-up device 21 are supplied to the input interface 22. The input interface 22 serves as an analog-to-digital converter for converting the analog image data into digital image data. More particularly, the picked up images are digitized by means of dividing the same into tiny pixels (data elements) isolated by grids. It is preferable to eliminate noises and distortions at this stage. The input interface 22 is also connected to a speed sensor 23, a steering gear ratio sensor 24 and a signal processor 30. The speed sensor 23 supplies velocity data to the signal processor 30 through the input interface 22. The velocity data represents an actual velocity of the automobile 10 at the time instant when the image pick-up device 21 picks up an image of a view. Likewise, the steering gear ratio sensor 24 supplies steering gear ratio data to the signal processor 30 through the input interface 22. The steering gear ratio data represents an actual steering gear ratio of the automobile 10.

The signal processor 30 comprises a central processing unit (CPU) 31, a read-only memory (ROM)

32 and a random-access memory (RAM) 33. CPU 31, ROM 32 and RAM 33 are operatively connected to each other through a data bus 34. To evade potentially dangerous objects, CPU 31 carries out calculation operation in response to the image, velocity and steering gear ratio data given through the input interface 22. CPU 31 performs proper functions according to programs stored in ROM 32 and RAM 33. The outputs of the signal processor 30 is transmitted through an output interface 40. ROM 32 stores a table relating to numerical values required for the calculation. It also stores a table representing operational amount for a safety drive ensuring arrangement 50. On the other hand, RAM 33 stores programs for use in calculating an optimum operational amount for the safety drive ensuring arrangement 50. A program for this purpose is disclosed in, for example, Teruo Yatabe, Automation Technique: Intelligent Vehicle, pages 22-28.

The signal processor 30 first determines, according to the picked up image data, whether there is a space available on the roadway to pass through. When there is enough space to pass through and a potentially dangerous object is present on the roadway, the signal processor 30 calculates optimum operational amount for the safety drive ensuring arrangement 50 to operate the same. In Fig. 1, the safety drive ensuring arrangement 50 consists of a steering actuator 51, a throttle actuator 52 and a brake actuator 53. If the signal processor 30 determines that it is necessary to operate these actuators, it produces steering gear ratio command, set velocity command, and brake operation command. The steering actuator 51, the throttle actuator 52 and the brake actuator 53 are operated depending on the condition in response to the steering gear ratio command, the set velocity command and the brake operation command, respectively.

The actuators are for use in actuating occupant protecting mechanism such as a brake device. Operation of these actuators is described now.

The steering actuator 51 is a hydraulic actuator for use in rotating steering wheel (not shown) in an emergency. In this event, the steering wheel is automatically rotated according to the steering gear ratio and rotational direction indicated by the steering gear ratio command. The operational amount of the steering or hydraulic actuator can be controlled in a well-known manner through a servo valve and a hydraulic pump, both of which are not shown in the figure.

The throttle actuator 52 acts to adjust opening amount of a throttle valve (not shown) to decrease speed while evading objects or so on.

The brake actuator 53 performs a function to gradually decrease speed of a vehicle in response to the brake operational command. The brake actuator 53 is also capable of achieving sudden brake operation, if necessary.

As mentioned above, CPU 31 carries out its operation with the tables and programs stored in ROM 32 and

RAM 33, respectively, for every one picked up image data. The conventional system is thus disadvantageous in that the calculation operation requires relatively long time interval as mentioned in the preamble of the instant specification.

On the contrary, a system according to the present invention uses image data representing ever-changing views picked up from a vehicle until it suffers from an accident. These image data are used for training a neural network implemented in the present system. After completion of the training, the neural network is implemented in a utility vehicle and serves as a decision making circuit for starting safety driving arrangements to evade crash, which otherwise will certainly be happened. The neural network predicts crash and evades the same by means of properly starting an automatic steering system or a brake system.

A well-known neural network is described first to facilitate an understanding of the present invention and, following which preferred embodiments of the present invention will be described with reference to the drawing.

A neural network is the technological discipline concerned with information processing system, which has been developed and still in their development stage. Such artificial neural network structure is based on our present understanding of biological nervous systems. The artificial neural network is a parallel, distributed information processing structure consisting of processing elements interconnected unidirectional signal channels called connections. Each processing element has a single output connection that branches into as many collateral connections as desired.

A basic function of the processing elements is described below.

As shown in Fig. 2, each processing element can receive any number of incoming functions while it has a single output connection that can be fan out into copies to form multiple output connections. Thus the artificial neural network is by far more simple than the networks in a human brain. Each of the input data  $x_1, x_2, \dots, x_i$  is multiplied by its corresponding weight coefficient  $w_1, w_2, \dots, w_i$ , respectively, and the processing element sums the weighted inputs and passes the result through a nonlinearity. Each processing element is characterized by an internal threshold or offset and by the type of nonlinearity and processes a predetermined transfer function to produce an output  $f(X)$  corresponding to the sum  $(X = \sum x_i \cdot w_i)$ . In Fig. 2,  $x_i$  represents an output of an  $i$ -th processing element in an  $(s-1)$ -th layer and  $w_i$  represents a connection strength or the weight from the  $(s-1)$ -th layer to the  $s$ -th layer. The output  $f(X)$  represents energy condition of each processing element. Though the neural networks come in a variety of forms, they can be generally classified into feedforward and recurrent classes. In the latter, the output of each processing element is fed back to other processing elements via weights. As described above, the network has

an energy or an energy function associated with it that will be minimum finally. In other words, the network is considered to have converged and stabilized when outputs no longer change on successive iteration. Means to stabilize the network depends on the algorithm used.

The back propagation neural network is one of the most important and common neural network architecture, which is applied to the present invention. In this embodiment, the neural network is used to determine if there is a possibility of crash. When the neural network detects the possibility of crash, it supplies an operational command to a safety ensuring unit in a manner described below. As well known in the art, the back propagation neural network is a hierarchical design consisting of fully interconnected layers of processing elements. More particularly, the network architecture comprises at least an input layer and an output layer. The network architecture may further comprise additional layer or N hidden layers between the input layer and the output layer where N represents an integer that is equal to or larger than zero. Each layer consists of one or more processing elements that are connected by links with variable weights. The net is trained by initially selecting small random weights and internal thresholds and then presenting all training data repeatedly. Weights are adjusted after every trial using information specifying the correct result until weights converge to an acceptable value. The neural network is thus trained to automatically generate and produce a desired output for an unknown input.

Basic learning operation of the back propagation neural network is as follows. First, input values are supplied to the neural network as the training data to produce output values, each of which is compared with a correct or desired output value (teacher data) to obtain information indicating a difference between the actual and desired outputs. The neural network adjusts the weights to reduce the difference between them. More particularly, the difference can be represented by a well-known mean square error. During training operation, the network adjusts all weights to minimize a cost function equal to the mean square error. Adjustment of the weights is achieved by means of back propagating the error from the output layer to the input layer. This process is continued until the network reaches a satisfactory level of performance. The neural network trained in the above mentioned manner can produce output data based on the input data even for an unknown input pattern.

The generalized delta rule derived with the steepest descent may be used to optimize the learning procedure that involves the presentation of a set of pairs of input and output patterns. The system first uses the input data to produce its own output data and then compares this with the desired output. If there is no difference, no learning takes place and otherwise the weights are changed to reduce the difference. As a result of this it becomes possible to converge the network after a rel-

atively short cycle of training.

To train the net weights on connections are first initialised randomly and input data (training data) are successively supplied to the processing elements in the input layer. Each processing element is fully connected to other processing elements in the next layer where a predetermined calculation operation is carried out. In other words, the training input is fed through to the output. At the output layer the error is found using, for example, a sigmoid function and is propagated back to modify the weight on a connection. The goal is to minimize the error so that the weights are repeatedly adjusted and updated until the network reaches a satisfactory level of performance. A graphical representation of sigmoid functions is shown in Fig. 3.

In this embodiment a sigmoid function as shown in Fig. 3 is applied as the transfer function for the network. The sigmoid function is a bounded differentiable real function that is defined for all real input values and that has a positive derivative everywhere. The central portion of the sigmoid (whether it is near 0 or displaced) is assumed to be roughly linear. With the sigmoid function it becomes possible to establish effective neural network models.

As a sigmoid function parameter in each layer, a y-directional scale and a y-coordinate offset are defined. The y-directional scale is defined for each layer to exhibit exponential variation. This results in improved convergence efficiency of the network.

It is readily understood that other functions may be used as the transfer function. For example, in a sinusoidal function a differential coefficient for the input sum in each processing element is within a range equal to that for the original function. To use the sinusoidal function results in extremely high convergence of training though the hardware for implementing the network may be rather complex in structure.

An embodiment of the present invention is described with reference to Figs. 4 through 9.

Fig. 4 is a block diagram of a system for predicting and evading crash of a vehicle using neural networks according to the first embodiment of the present invention. A system in Fig. 4 is similar in structure and operation to that illustrated in Fig. 1 other than a crash predicting circuit 60. Description of the similar components will thus be omitted by the consideration of evading redundancy. Fig. 5 is a schematic structural diagram of the crash predicting circuit 60 illustrated in Fig. 4 realized by a neural network of three layers.

The crash predicting circuit 60 in this embodiment is implemented by a neural network architecture of a hierarchical design with three layers as shown in Fig. 5(a). The input layer 61 consists of n processing elements 61-1 through 61-n arranged in parallel as a one-dimensional linear form. Each processing element in the input layer 61 is fully connected in series to the processing elements in a hidden layer 62 of the network. The hidden layer 62 is connected to an output

layer 63 of a single processing element to produce an operational command described below. Fig. 5(b) shows an input layer consisting of a two-dimensional array of processing elements. In this event, the image data are supplied to the input layer as a two-dimensional data matrix of  $n$  divisions. Basically, the input and the hidden layers can have any geometrical form desired. With the two-dimensional array, the processing elements of each layer may share the same transfer function, and be updated together. At any rate, it should be considered that each processing element is fully interconnected to the other processing elements in the next layer though only a part of which are shown in Fig. 5(a) to evade complexity.

Referring now to Fig. 6 in addition to Fig. 5, illustrated are views picked up, as the image data for use in training the neural network. The image pick-up device 21 picks up ever-changing images as analog image data as described above in conjunction with the conventional system. This image pick-up device 21 is also any one of suitable devices such as a CCD camera. The image pick-up operation is carried out during running of a vehicle at higher speed than a predetermined one. The image data are subject to sampling for a sampling range  $\Delta T$  during a predetermined sampling period  $\Delta t$ . The image data are collected before and just after pseudo crash. The image pick-up range of the image pick-up device 21 corresponds to a field of view observed through naked eyes. A view shown in Fig. 6(a) is picked up when a station wagon (estate car) 80a on the opposite lane comes across the center line. A view shown in Fig. 6(b) is picked up when an automobile 80b suddenly appears from a blind corner of a cross-street. These ever-changing images are collected as the training data for the neural network.

The image data effectively used for the crash evade purpose are those which allow continuous recognition of the ever-changing views before and just after pseudo crash. With this respect, the image pick-up device 21 picks up the images of a vehicle or other obstructions located at a relatively short headway. In addition, the picked up images preferably are distinct reflections of the outside views.

The data elements consisting of one image are simultaneously supplied to the input layer 61 in parallel. In other words, each data element is supplied to the respective processing element of the input layer 61. The digital image data may be normalized before being supplied to the input layer 61 to increase a data processing speed. However, each processing element of the input layer 61 essentially receives the data element obtained by dividing the image data previously. The data elements are subjected to feature extraction when supplied to the hidden layer 62.

In typical image processing, feature extraction is carried out according to any one of various methods of pattern recognition to clearly identify shapes, forms or configurations of images. The feature-extracted data

are quantized to facilitate subsequent calculations. In this event, separate analytical procedure is used for region partitioning or for extraction of configuration strokes. In other words, a particular program is necessary for each unit operation such as region partitioning, feature extraction, vectorization and so on. Compared with this, the prediction system according to the present invention requires no program based on each operation or procedure because a unique algorithm is established on completion of network training. This single algorithm allows to perform necessary functions without using separate algorithms or programs.

In a preferred embodiment, the feature extraction is directed to the configuration of an object defining the driving lanes such as shoulders, curbs, guard rails or the center line. The feature may also be extracted on regions such as carriageways. The neural network learns these configurations and regions during training process. This process is continued until the network reaches a satisfactory level of performance. The neural network is thus trained while carrying out feature extraction on the input image. Weights are adjusted after every trial on the quantized image data, so that the latest training data is weighted according to the latest result of adjustment and then supplied to the hidden layer 62. In addition, the neural network can be trained with image data including an object at time-varying positions. In this event, any one of suitable methods may be used for digital image processing.

In the present embodiment, each digital data indicative of ever-changing view at a certain sampling time instance is divided into  $n$  data elements. A product of  $n$  represents a positive integer which is equal in number to the processing elements in the input layer 61. In other words, the series of time sequential data is picked up as continuous  $n$  data elements to be supplied in parallel to the  $n$  by  $m$  processing elements in the input layer 61 as the training data. At the same time, an operational signal is supplied to the output layer 63 of the network as teacher data. The operational signal may be a logic "1" for representing crash of the automobile 10 after elapse of a predetermined time interval from the sampling time instant corresponding to the image data just having been supplied to the input layer 61.

In the same manner, the picked up image data and its corresponding teacher data are successively supplied to the crash predicting circuit 60. The crash predicting circuit 60 is continuously trained until the network reaches a satisfactory level of performance. After completion of training, the network is capable of matching the picked up image with the possibility of crash. The accuracy of prediction is improved by means of supplying images for a case of "safe" state to the neural network on learning.

The neural network thus learns the relative position between the vehicle on which it is mounted and objects at a short headway. As a result of this learning, the crash predicting circuit 60 enables to prediction of crash

expected to be happened a few seconds later according to this relative position. While outside views change every moment and a vehicle in practice encounters various objects and situations, a series of repeated training can yield stereotyped data patterns.

The neural network program that has already been trained can be memorized in a read only memory (ROM) as an application. In this event the network program is memorized after being compiled and translated into a machine language. The ROM is implemented in a predetermined IC chip or the like as an inherent circuit. The IC chip is mounted on a circuit for the air bag system in an automobile.

As mentioned above, the crash predicting circuit 60 supplies the operational signal to the safety drive ensuring arrangement 50 when it predicts occurrence of crash. In response to this operational signal the safety drive ensuring arrangement 50 can perform proper function to evade crash.

For more clear understanding of the present invention, two cases are described those results in "safe" state of the automobile 80c, 80d. Fig. 7 shows an exemplified image including an oncoming vehicle 80c running on the opposite lane. The situation being far from danger as shown in Fig. 7 may allow the system of the present invention to bypass the crash predicting circuit 60. Alternatively, the crash predicting circuit 60 may produce an operational signal of logic "0" to represent this "safe" condition.

A view shown in Fig. 8 represents a situation when a vehicle 80d on the opposite lane comes across the center line in the far distance ahead. The vehicle 80d is going to return to the lane where it ought to be. The subsequent image data indicate that the oncoming vehicle 80d takes an action to evade crash. In other words, the oncoming vehicle 80d is expected to return to the proper lane before the vehicle mounting the crash predicting circuit 60 passes by the vehicle 80d. Accordingly, the crash predicting circuit 60 determines that there are no hazardous objects ahead.

If a vehicle on the opposite lane comes across the center line or a vehicle suddenly appears from a blind corner of a cross-street as shown in Figs. 5(a) and 5(b), the crash predicting circuit 60 carries out prediction operation in accordance with the image data showing these situations. Expected hazards make the crash predicting circuit 60 actuate the safety drive ensuring arrangement 50 in the manner described above.

Another embodiment of the present invention will be described below in which the neural network comprises an intermediate layer having a self-organization function and a competitive learning function to positively respond to various unknown data with less training data. As well known in the art, in the self-organization a network modifies itself in response to inputs. Examples of the use of self-organizing training include the competitive learning law applied to the present embodiment.

As shown in Fig. 9 the neural network according to

this embodiment comprises a two-dimensional self-organized competitive learning layer 64 interposed between the input layer 61 and the hidden layer 62. The two-dimensional self-organized competitive learning layer 64 is referred as to the two-dimensional Kohonen layers (2D-K layer) which in this embodiment comprises  $p$  by  $q$  layers consisting of a two-dimensional array of processing elements. The input layer 61 may consists of either one or two-dimensional array of processing elements. The 2D-K layer 64 can have any geometrical form desired. In this embodiment, it is also considered that each processing element is fully interconnected to the other processing elements in the next layer though only a part of which are shown in Fig. 9 to evade complexity.

The processing elements in the 2D-K layer 64 compete with one another to determine the "winner" on the basis of minimum distance. More particularly, a predetermined distance can be obtained by, in this embodiment,  $n$  processing elements for each set of the input data. The similarity for each of the  $n$  input data corresponds to the distance to select similar combination of processing elements. The selected processing elements becomes "winner" for facilitating determination on attributes of unknown data.

More particularly, the winning three Kohonen's processing elements are determined among the fourth processing elements to supply output data. Unknown data are preprocessed on the basis of classification for the input data due to the self-organization on learning. The output value thereof is supplied to the subsequent hidden layer.

With an additional normalization layer 65 may be interposed between the input layer 61 and the 2D-K layer 64 as shown in Fig. 9. With this normalization layer 65, the learning efficiency in the 2D-K layer 64 will be sufficiently improved. Addition of the 2D-K layer 64 contributes to a surprising number of information processing capabilities for unknown data as well as a remarkably improved convergence efficiency on learning.

The neural network having the 2D-K layer can be completed by means of expanding the above mentioned back propagation method so that the learning procedure can be determined in a similar manner as in the back propagation method.

The self-organization requires that the system uses, during adaptation of initial several thousands times, no other information other than the incoming patterns and no data are fed back from the output layer. After completion of self-organization the network is trained according to the back propagation algorithm. The neural network having a structure according to this embodiment can be trained with less data for a shorter period of training cycle.

In the above mentioned second embodiment, the neural network already trained can be coded by using a programming language such as C-language. The net-



work may be used as an imperative application system or packaged as a control microprocessor. In this event, the network can be memorized in a read only memory for every one type of commercial vehicles.

For the portion of algorithm that is established readily in logical, a well-known expert system may be applied to achieve a prediction system using a combination of logic circuit for the neural network and the expert system.

While the above embodiments have thus been described in conjunction with automatic crash evasive operation, it is possible to give precedence to the driver's operation. For example, it is possible to issue appropriate warnings to the driver before actuation of the safety drive ensuring arrangement 50. For this purpose, an audible signal such as an alarm sound may be generated to alert the driver to potential hazards.

#### Claims

1. An apparatus for predicting and evading potential crash of a vehicle and predicting real crash of a vehicle and acting correspondingly, comprising:

image pick-up means mounted on the vehicle for picking up images of actual ever-changing views when the vehicle is on running to produce actual image data;

crash predicting means comprising a neural network associated with said image pick-up means, said crash predicting means successively supplied with the actual image data for predicting potential occurrence of crash between the vehicle and potentially dangerous objects to produce an operational signal when there is possibility of crash,

safety drive ensuring means connected to said crash predicting means for actuating, in response to the operational signal, predicting potential or real crash,

**characterized in that**

an occupant protecting mechanism including an airbag is provided,

said neural network being adapted and trained to predict real occurrence of a crash and being connected with said airbag, to release said airbag in case of real crash,

a safety drive ensuring arrangement is provided,

said neural network being adapted and trained to predict occurrence of potential crash and being connected with said safety drive ensuring arrangement to perform proper function to evade crash,

said neural network therefore being trained with training data to predict the possibility of potential occurrence and real occurrence of crash, the training data representing ever-

changing views previously picked up during driving of the vehicle and after real crash.

2. Apparatus according to claim 1, **characterized in that**

means for producing an audible signal to alert the driver to potential occurrence of crash are provided.

3. Apparatus according to claim 1, **characterized in that**

said neural network comprises at least an input layer and an output layer, and training data are supplied to the input layer while the output layer is supplied with, as teacher data, flags representing "crash expected" and "no crash expected", respectively, of the vehicle.

4. Apparatus according to claim 3, **characterized in that**

said neural network comprises a two-dimensional self-organizing competitive learning layer as an intermediate layer.

5. Apparatus according to claim 1, **characterized in that**

said neural network is coded after completion of learning and implemented in the vehicle.

6. Apparatus according to claim 1, **characterized in that**

said safety drive ensuring means includes a steering actuator and the occupant protecting mechanism includes a steering system of the vehicle.

7. Apparatus according to claim 1, **characterized in that**

said safety drive ensuring means includes a throttle actuator and the occupant protecting mechanism includes a throttle system of the vehicle.

8. Apparatus according to claim 1, **characterized in that**

said safety drive ensuring means includes a brake actuator and the occupant protecting mechanism includes a brake system of the vehicle.



9. Method for predicting and evading potential crash of a vehicle and for predicting real crash of a vehicle and acting correspondingly, comprising:

image pick-up means mounted on the vehicle for picking up images of actual ever-changing views when the vehicle is on running to produce actual image data;  
 crash predicting means comprising a neural network associated with said image pick-up means, said crash predicting means successively supplied with the actual image data for predicting potential occurrence of crash between the vehicle and potentially dangerous objects to produce an operational signal when there is possibility of crash,  
 safety drive ensuring means, connected to said crash predicting means for actuating, in response to the operational signal, the occupant protecting mechanism including an air-bag,  
 and a safety drive ensuring arrangement to perform proper function to evade crash, which are operatively connected thereto and equipped in the vehicle,  
 whereby  
 said neural network contains previously taken image data formed of successive scenes for causing accidents and is trained by a back propagation method for realizing conditions of causing said accidents, whereby the training of said neural network is performed by supplying training data to an input layer of said neural network while an output layer of said neural network is supplied with, as teacher data, flags representing "crash expected" and "no crash expected",  
 respectively, of the vehicle,  
 said neural network evaluates the actual image data by itself,  
 said neural network judges if the vehicle collides with the objects noticed in the actual image data of the image pick-up means, and outputs said operational signal in case of prediction of occurrence of a crash with said object.

10. Method according to claim 9, characterized in that

said neural network comprises a two-dimensional self-organizing competitive learning layer as an intermediate layer.

11. Method according to claim 9, characterized in that

said neural network is coded after completion of learning and implemented in the vehicle.

## Patentansprüche

1. Vorrichtung zum Vorhersagen und Vermeiden eines potentiellen Zusammenstoßes eines Fahrzeugs und zum Vorhersagen eines realen Zusammenstoßes eines Fahrzeugs und zum entsprechenden Agieren, mit:

einer Bildaufnahmeeinrichtung, die auf dem Fahrzeug angebracht ist, um Bilder von aktuellen, ständig wechselnden Ansichten aufzunehmen, wenn das Fahrzeug fährt, um aktuelle Bilddaten zu erzeugen;

einer Zusammenstoß-Vorhersageeinrichtung mit einem neuronalen Netzwerk, das der Bildaufnahmeeinrichtung zugeordnet ist, wobei der Zusammenstoß-Vorhersageeinrichtung sukzessive die aktuellen Bilddaten zum Vorhersagen eines potentiellen Auftretens eines Zusammenstoßes zwischen dem Fahrzeug und potentiell gefährlichen Objekten zugeführt sind, um ein Operationssignal zu erzeugen, wenn die Möglichkeit eines Zusammenstoßes besteht,

einer Einrichtung zur Gewährleistung der Fahrsicherheit, die mit der Zusammenstoß-Vorhersageeinrichtung verbunden ist, um in Reaktion auf das Operationssignal, das einen potentiellen oder realen Zusammenstoß vorhersagt, betätigt zu werden,

dadurch gekennzeichnet, daß

ein Insassenschutzmechanismus mit einem Airbag vorgesehen ist,

das neuronale Netzwerk zur Vorhersage eines realen Auftretens eines Zusammenstoßes angepaßt und trainiert ist und mit dem Airbag verbunden ist, um den Airbag im Fall eines realen Zusammenstoßes auszulösen,

eine Anordnung zur Gewährleistung der Fahrsicherheit vorgesehen ist,

das neuronale Netzwerk zur Vorhersage des Auftretens eines potentiellen Zusammenstoßes angepaßt und trainiert ist und mit der Anordnung zur Gewährleistung der Fahrsicherheit verbunden ist, um eine geeignete Funktion zur Vermeidung eines Zusammenstoßes durchzuführen,

das neuronale Netzwerk daher mit Trainingsdaten trainiert ist, um die Möglichkeit des potentiellen Auftretens und des realen Auftretens eines Zusammenstoßes vorherzusagen, wobei die Trainingsdaten ständig wechselnde, früher aufgenommene Ansichten darstellen, die während des Fahrens eines Fahrzeuges und nach einem realen Zusammenstoß aufgenommen sind.

2. Vorrichtung nach Anspruch 1,

dadurch gekennzeichnet,

daß eine Einrichtung zur Erzeugung eines hörbaren Signals vorgesehen ist, um den Fahrer vor dem potentiellen Auftreten eines Zusammenstoßes zu warnen.

3. Vorrichtung nach Anspruch 1,  
dadurch gekennzeichnet,

daß das neuronale Netzwerk mindestens eine Eingabeschicht und eine Ausgabeschicht aufweist, und Trainingsdaten der Eingabeschicht zugeführt werden, während der Ausgabeschicht als Lerndaten Kennzeichen zugeführt werden, die "Zusammenstoß erwartet" beziehungsweise "kein Zusammenstoß erwartet" des Fahrzeugs repräsentieren.

4. Vorrichtung nach Anspruch 3,  
dadurch gekennzeichnet,

daß das neuronale Netzwerk eine zweidimensionale, selbstorganisierende kompetitive Lernschicht als Zwischenschicht aufweist.

5. Vorrichtung nach Anspruch 1,  
dadurch gekennzeichnet,

daß das neuronale Netzwerk nach Abschluß des Lernens kodiert und in dem Fahrzeug implementiert ist.

6. Vorrichtung nach Anspruch 1,  
dadurch gekennzeichnet,

daß die Einrichtung zur Gewährleistung der Fahrsicherheit eine Steuerungsbetätigung aufweist und der Insassenschutzmechanismus ein Steuerungssystem des Fahrzeugs aufweist.

7. Vorrichtung nach Anspruch 1,  
dadurch gekennzeichnet,

daß die Einrichtung zur Gewährleistung der Fahrsicherheit eine Drosselklappenbetätigung aufweist und der Insassenschutzmechanismus ein Drosselklappensystem des Fahrzeugs aufweist.

8. Vorrichtung nach Anspruch 1,  
dadurch gekennzeichnet,

daß die Einrichtung zur Gewährleistung der Fahrsicherheit eine Bremsenbetätigung aufweist und der Insassenschutzmechanismus ein Bremsensystem des Fahrzeugs aufweist.

9. Verfahren zum Vorhersagen und Vermeiden eines potentiellen Zusammenstoßes eines Fahrzeugs und zum Vorhersagen eines realen Zusammenstoßes eines Fahrzeugs und zum entsprechenden Agieren, mit:

einer Bildaufnahmeeinrichtung, die auf dem Fahrzeug zur Aufnahme von Bildern von aktuellen, ständig wechselnden Ansichten angebracht ist, wenn das Fahrzeug fährt, um aktuelle Bilddaten zu erzeugen;

einer Zusammenstoß-Vorhersageeinrichtung mit einem neuronalen Netzwerk, das der Bildaufnahmeeinrichtung zugeordnet ist, wobei der Zusammenstoß-Vorhersageeinrichtung sukzessive die aktuellen Bilddaten zur Vorhersage des potentiellen Auftretens eines Zusammenstoßes zwischen dem Fahrzeug und potentiell gefährlichen Objekten zugeführt werden, um ein Operationssignal zu erzeugen, wenn die Möglichkeit eines Zusammenstoßes besteht, einer Einrichtung zur Gewährleistung der Fahrsicherheit, die mit der Zusammenstoß-Vorhersageeinrichtung verbunden ist, um in Reaktion auf ein Operationssignal betätigt zu werden, wobei der Insassenschutzmechanismus einen Airbag aufweist, und

einer Anordnung zur Gewährleistung der Fahrsicherheit, um eine geeignete Funktion zum Vermeiden eines Zusammenstoßes durchzuführen, die operativ damit verbunden und in dem Fahrzeug vorgesehen ist, wobei das neuronale Netzwerk früher aufgenommene Bilddaten enthält, die von aufeinanderfolgenden Szenen beim Verursachen eines Unfalls gebildet werden und durch ein Rück-Propagation-Verfahren zum Realisieren von Verhältnissen, die Unfälle verursachen, trainiert ist, wobei das Training des neuronalen Netzwerks durch Zuführen von Trainingsdaten zu einer Eingabeschicht des neuronalen Netzwerks durchgeführt wird, während eine Ausgabeschicht des neuronalen Netzwerks mit Kennzeichen als Lerndaten versorgt wird, die "Zusammenstoß erwartet" und "kein Zusammenstoß erwartet" des Fahrzeugs repräsentieren, das neuronale Netzwerk die aktuellen Bilddaten selbst bewertet, das neuronale Netzwerk beurteilt, ob das Fahrzeug mit den beobachteten Objekten in den aktuellen Bilddaten der Bildaufnahmeeinrichtung kollidiert und das Operationssignal im Falle einer Vorhersage des Auftretens eines Zusammenstoßes mit dem Objekt ausgibt.

10. Verfahren nach Anspruch 9,  
dadurch gekennzeichnet,

daß das neuronale Netzwerk eine zweidimensionale, selbstorganisierende kompetitive Lernschicht als Zwischenschicht aufweist.

#### 11. Verfahren nach Anspruch 9, dadurch gekennzeichnet,

daß das neuronale Netzwerk nach Vollendung des Lernens kodiert und in dem Fahrzeug implementiert wird.

#### Revendications

1. Appareil pour prédire et prévenir une collision potentielle d'un véhicule et pour prédire une collision réelle d'un véhicule et agir en conséquence, comprenant:

un moyen de saisie d'image monté sur le véhicule pour saisir, quand le véhicule roule, des images de vues réelles constamment changeantes, afin de produire des données d'images réelles;

un moyen de prédiction de collision comprenant un réseau neuronal associé audit moyen de saisie d'image, ledit moyen de prédiction de collision étant alimenté successivement avec les données d'images pour prédire la survenue potentielle d'une collision entre le véhicule et des objets potentiellement dangereux afin de produire un signal d'opération lorsqu'il existe un risque de collision;

un moyen assurant une conduite sûre, relié au moyen de prédiction de collision pour un actionnement, en réponse au signal d'opération, et pour une prédiction de collision potentielle ou réelle,

caractérisé en ce que:

un mécanisme de protection d'occupant comprenant un coussin gonflable est présent, ledit réseau neuronal étant adapté et éduqué de manière à prédire la survenue réelle d'une collision et étant relié audit coussin gonflable pour déclencher le fonctionnement dudit coussin gonflable en cas de collision réelle,

un agencement assurant une conduite sûre est prévu, ledit réseau neuronal étant adapté et éduqué de manière à prédire la survenue d'une collision potentielle et étant relié audit agencement assurant une conduite sûre afin de remplir une fonction appropriée pour prévenir une collision,

ledit réseau neuronal étant par conséquent éduqué avec des données d'éducation de manière à prédire le risque de la survenue potentielle et de la survenue réelle d'une collision, les données d'éducation représentant des vues constamment changeantes saisies

antérieurement pendant que le véhicule roule et après une collision réelle.

2. Appareil selon la revendication 1, caractérisé en ce qu'un moyen servant à produire un signal audible pour avertir le conducteur d'une survenue potentielle de collision est présent.

3. Appareil selon la revendication 1, caractérisé en ce que ledit réseau neuronal comprend au moins une couche d'entrée et une couche de sortie, et que les données d'éducation sont fournies à la couche d'entrée pendant que la couche de sortie reçoit, en tant que données d'éducateur, des indicateurs représentant une "collision prévue" et "aucune collision prévue" du véhicule, respectivement.

4. Appareil selon la revendication 3, caractérisé en ce que le réseau neuronal comprend, en tant que couche intermédiaire, une couche bidimensionnelle d'apprentissage compétitif s'auto-organisant

5. Appareil selon la revendication 1, caractérisé en ce que ledit réseau neuronal est codé après achèvement de l'enseignement et est intégré dans le véhicule.

6. Appareil selon la revendication 1, caractérisé en ce que ledit moyen assurant une conduite sûre comprend un actionneur de direction et le mécanisme de protection d'occupant comprend le système de direction du véhicule.

7. Appareil selon la revendication 1, caractérisé en ce que ledit moyen assurant une conduite sûre comprend un actionneur de papillon des gaz et le mécanisme de protection d'occupant comprend le système de papillon des gaz du véhicule.

8. Appareil selon la revendication 1, caractérisé en ce que le moyen assurant une conduite sûre comprend un actionneur de freins et le mécanisme de protection d'occupant comprend le système de freins du véhicule.

9. Procédé pour prédire et prévenir une collision potentielle d'un véhicule et pour prédire une collision réelle d'un véhicule et agir en conséquence, comprenant:

un moyen de saisie d'image monté sur le véhicule pour saisir, quand le véhicule roule, des images de vues réelles constamment changeantes afin de produire des données d'images réelles;

un moyen de prédiction de collision comprenant un réseau neuronal associé audit moyen de saisie d'images, ledit moyen de prédiction

de collision recevant de façon successive les données d'images réelles pour prédire la survenue potentielle d'une collision entre le véhicule et des objets potentiellement dangereux afin de produire un signal d'opération quand il existe un risque de collision,

un moyen assurant une conduite sûre, relié audit moyen de prédiction de collision pour actionner, en réponse au signal d'opération, le mécanisme de protection comprenant un coussin gonflable, et un agencement assurant une conduite sûre pour remplir une fonction appropriée afin de prévenir une collision, qui y sont reliés fonctionnellement et montés dans le véhicule,

grâce à quoi ledit réseau neuronal contient des données d'images saisies antérieurement, formées de scènes successives entraînant des accidents et est éduqué par un procédé de rétro-propagation servant à réaliser les conditions entraînant lesdits accidents, l'éducation dudit réseau neuronal étant effectuée par fourniture de données d'éducation à une couche d'entrée dudit réseau neuronal pendant qu'une couche de sortie dudit réseau neuronal reçoit, en tant que données d'éducateur, des indicateurs représentant une "collision prévue" et "aucune collision prévue" du véhicule, respectivement,

ledit réseau neuronal évalue par lui-même les données d'images réelles,

ledit réseau neuronal juge si le véhicule heurte les objets mentionnés dans les données d'images réelles du moyen de saisie d'images et émet ledit signal d'opération dans le cas d'une prédiction de survenue d'une collision avec ledit objet.

10. Procédé selon la revendication 9, caractérisé en ce que ledit réseau neuronal comprend, en tant que couche intermédiaire, une couche bidimensionnelle d'apprentissage compétitif s'auto-organisant.

11. Procédé selon la revendication 9, caractérisé en ce que ledit réseau neuronal est codé après achèvement de l'enseignement et est intégré dans le véhicule.

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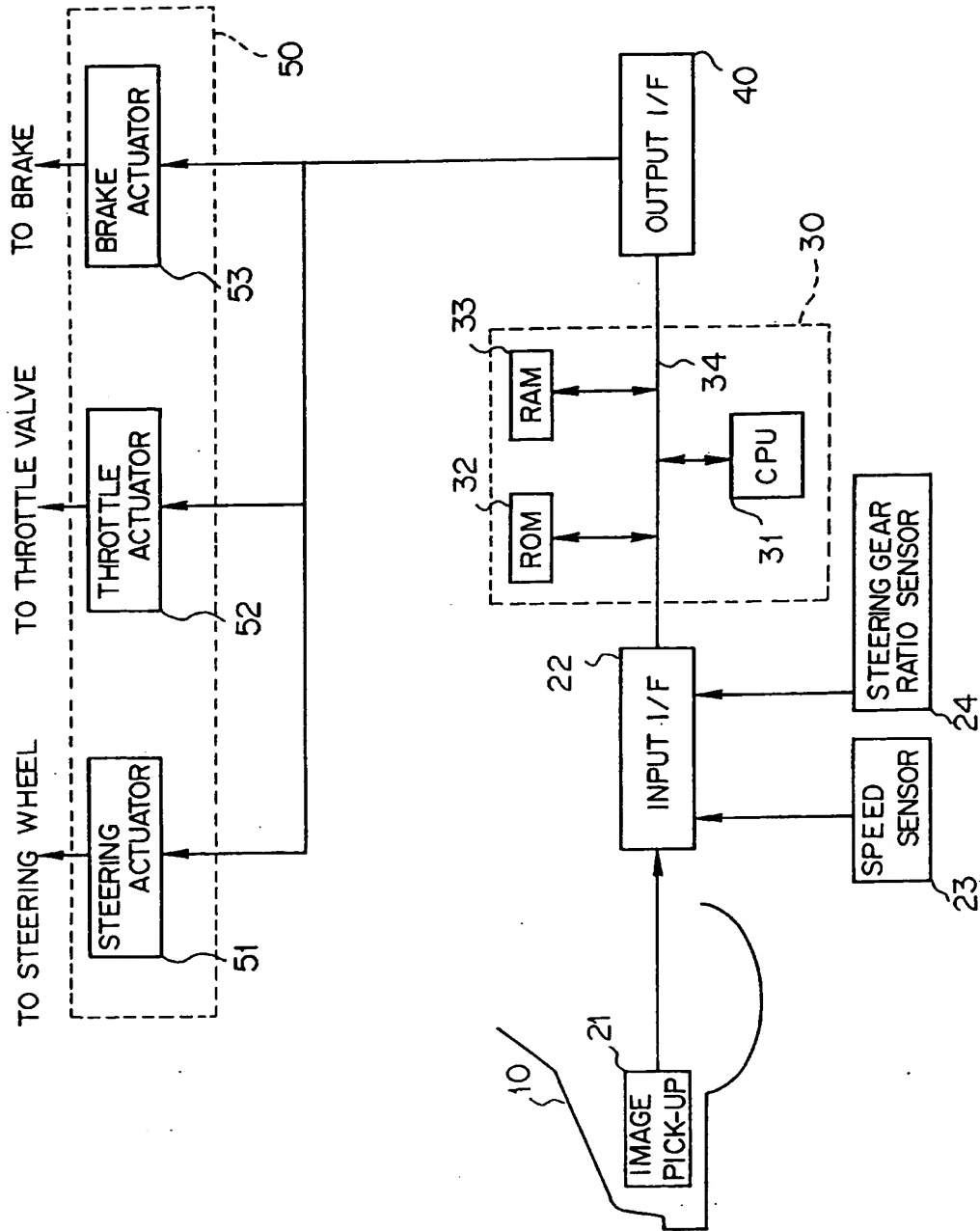


FIG. 1 PRIOR ART

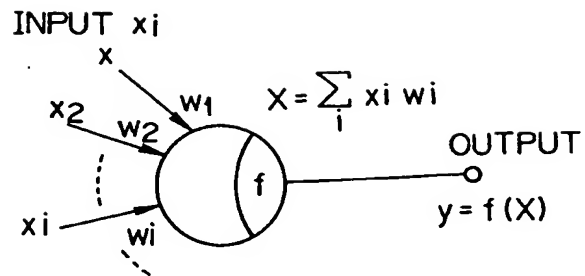


FIG. 2  
PRIOR ART

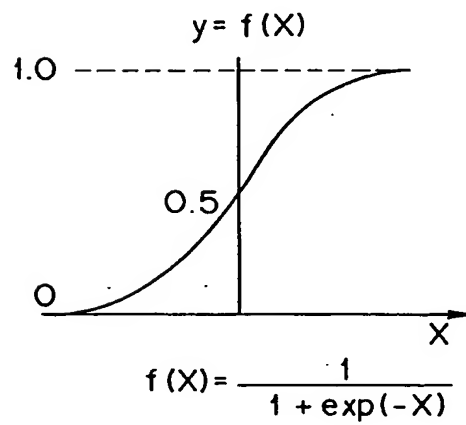


FIG. 3  
PRIOR ART

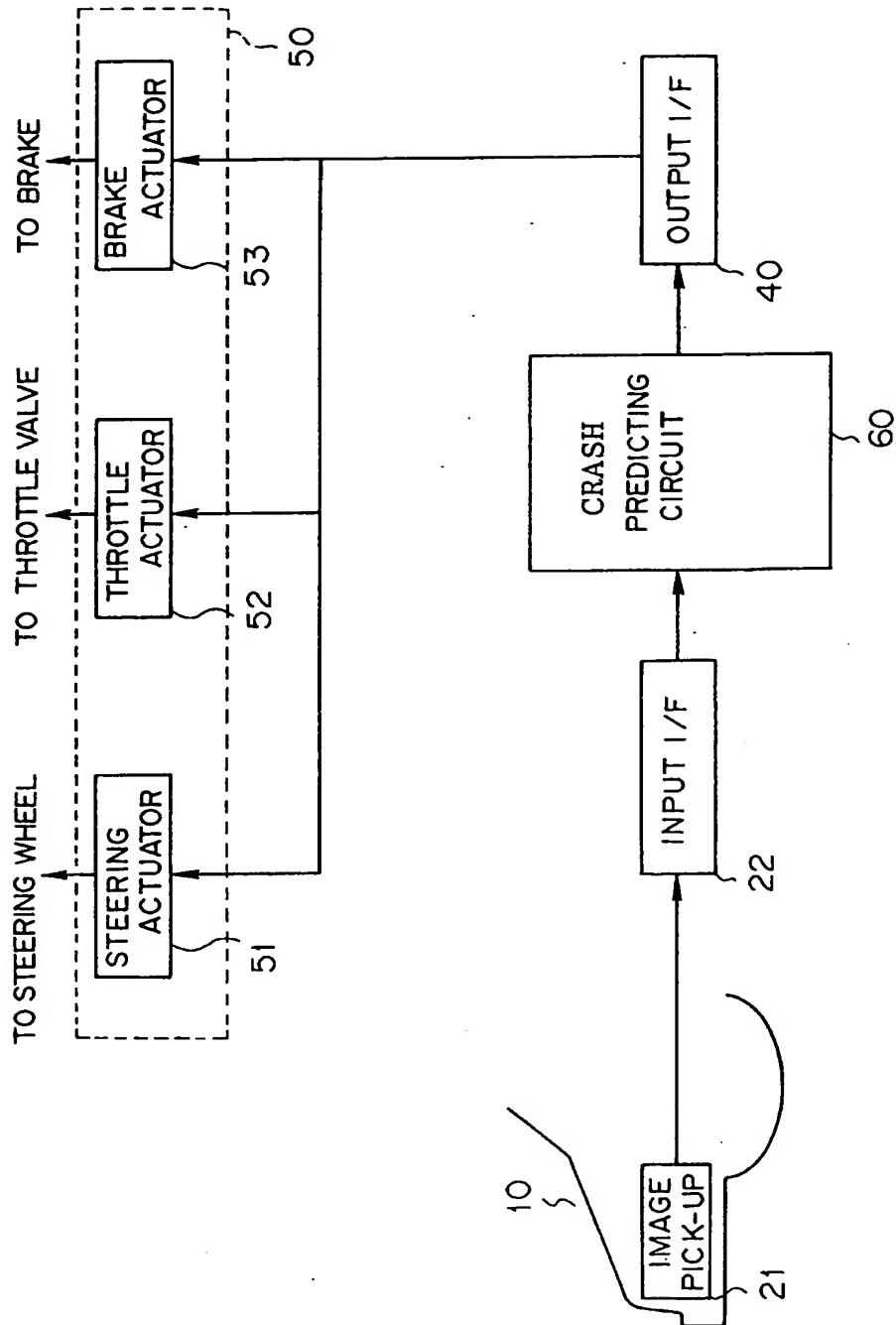
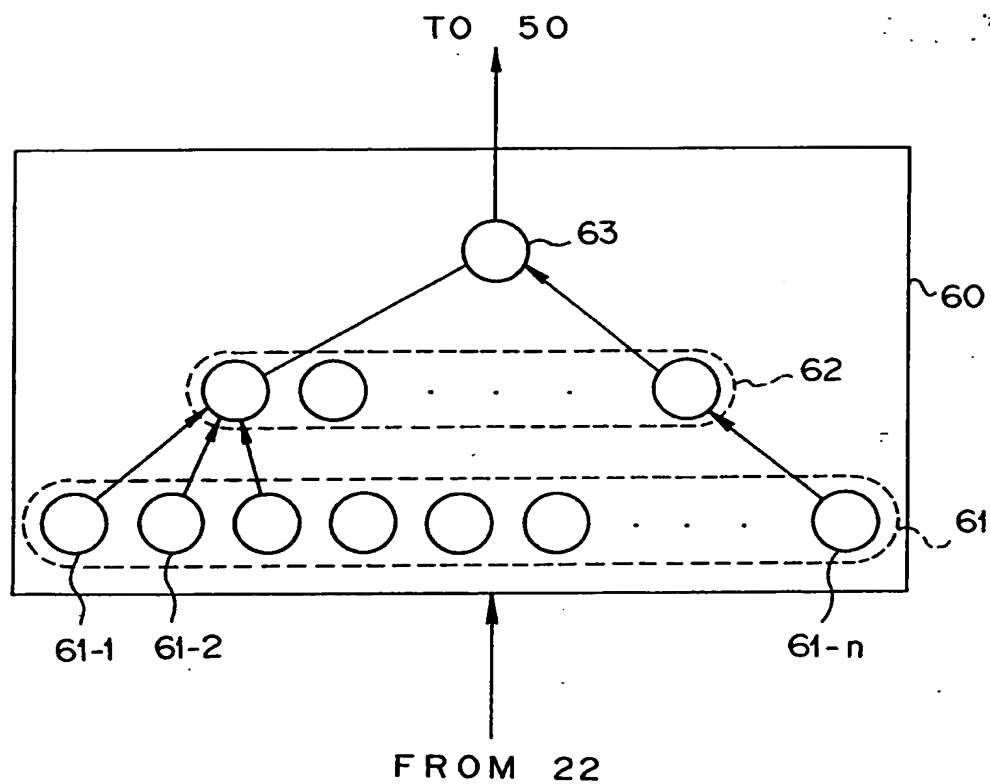
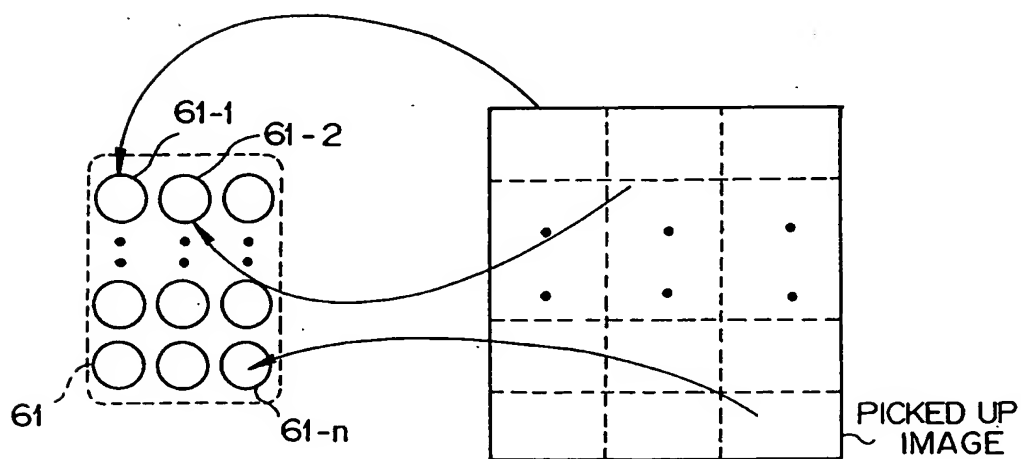


FIG. 4



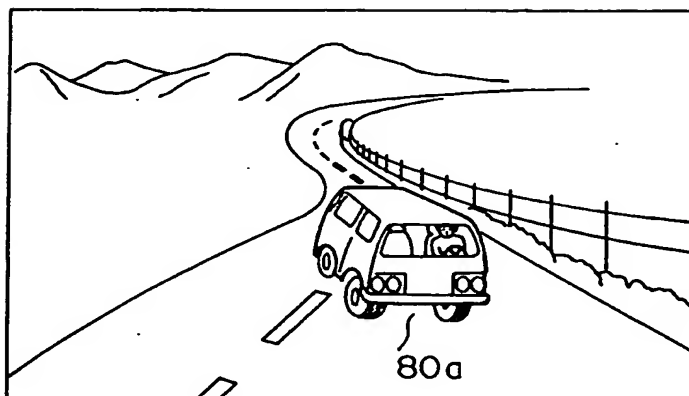


(a)

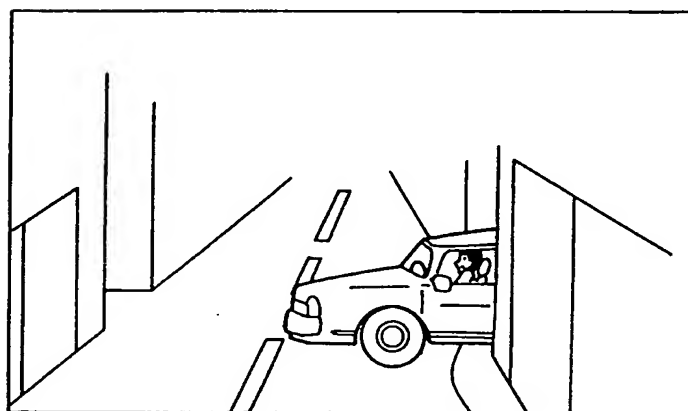


(b)

FIG. 5



(a)



(b) 80b

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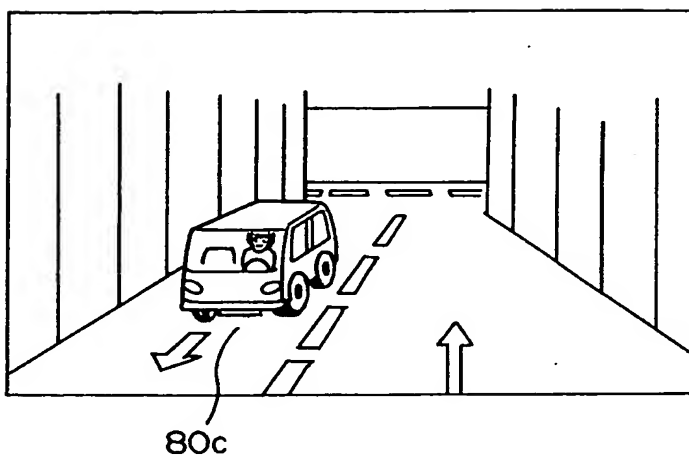


FIG. 7

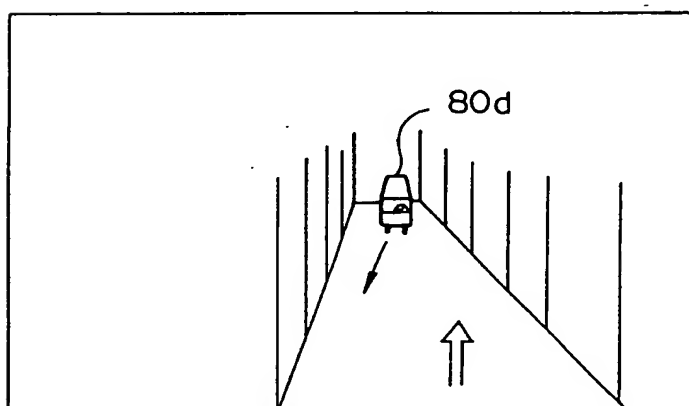


FIG. 8

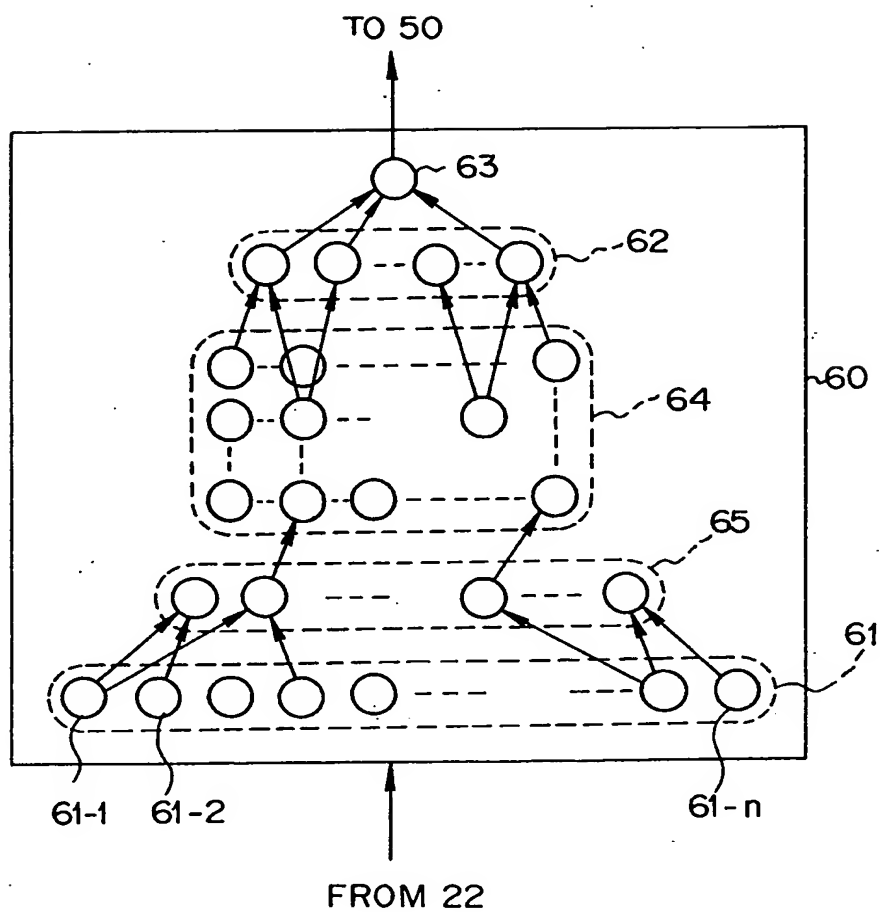


FIG. 9